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ABSTRACT

Designed to obtain information on the tests and activities in which students engage in science classes, this study focused on the activity structures used by teachers in high school science classes and on the academic work of students. The main component of the study was an ethnographic investigation of 15 science teachers from Perth, Australia. It was found that whole class interactive activities were used more than 50 percent of the time. Non-interactive activities in which teachers presented information to the whole class, as well as individual seatwork activities, also occurred frequently. Small group activities tended to occur only when students collected data during an investigation. The academic work was influenced by the assessment system and teacher expectations for student performance and achievement. Teachers endeavored to cover the curriculum in the prescribed time whether or not learning occurred. Students were often expected to engage in two or more activities simultaneously, and the cognitive demands of the work were low. Bibliographic notes are included. (ML)

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Academic Work in High School Science Classrooms

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ABSTRACT

Fifteen teachers in two high schools in the suburbs of Perth, Western Australia participated in a qualitative investigation of work in science classes. When teachers implemented the curriculum they used whole class interactive activities for more than 50% of the time. Non-interactive activities in which teachers presented information to the class as a whole, and seatwork activities in which students engaged in tasks such as note-taking and completing worksheets also occurred frequently. Small group activities tended to occur only when students collected data during an investigation.

The academic work was influenced by the assessment system and teacher expectations for student performance and achievement. Teachers endeavored to cover the curriculum in the prescribed time whether or not learning occurred, students were often expected to engage in two or more activities simultaneously, and the cognitive demands of the work were low.

ACADEMIC WORK IN HIGH SCHOOL SCIENCE CLASSROOMS

When the teacher closes the door to the classroom and begins to teach, the lesson that unfolds is known only to the teacher and the thirty or so students in that class. Each day, a similar scenario occurs in most classrooms. Little information about the implemented curriculum filters to the outside world. How do teachers and students go about their work in classrooms? What activities are most frequently used to engage students? How do teachers assist students to learn? These are just a few fundamental questions that need answers. Such questions need to be asked and the answers that are received should be subjected to close scrutiny. Yet what is the source of the answers? Researchers need to study classrooms, construct a picture of classroom life, and communicate their findings to those with an interest in curriculum design and implementation.

High school science was the selected context for this study because of the emphasis placed on learning higher cognitive level knowledge in that subject. Despite this emphasis, for at least 20 years, there is evidence to suggest that many students do not attain higher cognitive level goals when they participate in science courses (Tobin, Capie & Bettencourt, in press). An examination of the implemented science curriculum could quite possibly highlight reasons for the relative lack of success of high school science curricula. Consequently, an important reason for conducting this study was to describe academic work in high school science classrooms, and to develop an understanding of the forces which mold the implemented curriculum.

The nature of student work in science classes is dependent (at least in part) on the tasks assigned by the teacher, the cognitive engagement of individual learners as they participate in learning tasks, interactions between learners and the teacher during instruction, and aspects of the activity setting, such as group structure, which provide a context for classroom learning. In most classes, the teacher has responsibility for initiating activities, maintaining activity flow, and monitoring student

work. These responsibilities are an important part of the work that teachers do in the classroom, and clearly, the nature of teacher work has direct effects on student work. In science classes, student work consists of activities such as working from the textbook, completing worksheets, taking notes, listening to a lecture, planning an investigation, collecting data, interpreting results, constructing a graph, and watching a film. These activities differ from one another in terms of content, cognitive demand, the extent to which engagement was overt, and group structure.

The manner in which a teacher sets up a science classroom and engages students is probably dependent on what the teacher intends students to learn and how the teacher believes students learn. Constructivism (von Glasersfeld, 1982) is an epistemology which highlights the central role of the learner in the learning process. The constructivist science classroom assumes that knowledge acquisition occurs as a result of personal actions on data which are derived from active engagement in activities in which students discuss ideas and problems with their peers, manipulate equipment, work independently, listen to the teacher in whole class settings, and respond to teacher questions. Because knowledge is personalized, active teaching is required to monitor student understandings, and to facilitate learning through the use of cues, prompts, and clarifications. A contrast to the constructivist classroom is a classroom environment based on the "siphon" model of learning. This classroom has students involved in predominantly covert ways as information is transferred to the students' heads from the teacher's head or from a textbook. The constructivist and siphon classrooms are at the ends of a continuum related to student engagement. We cannot say for sure that science classes are based on one model or the other. In fact it is likely that some activities will be taught according to one model and others will be taught by the same teacher based on the other model. We don't really know too much about the implemented science curriculum. The purpose of this study was to learn more about the tasks and activities in which students engage in science classes.

This paper presents results pertaining to the activity structures used in high school science classes and the academic work of students. Other results of the study are available in papers which describe the disproportionate involvement of target students in science activities (Tobin & Gallagher, in press), gender differences in science activities (Tobin & Garnett, in press), classroom management (Gallagher & Tobin, in press), and the role of laboratory activities in science (Tobin, 1986).

CONTEXTUAL INFORMATION

In this study a variety of state-mandated curricula were implemented in two Western Australian high schools which are referred to as Private school and Public school. At grade 8 level all students studied a general science course consisting of nine topics. Students in grade 8 were placed in groups that were heterogeneous with respect to science ability.

Eighteen additional science topics were studied in grades 9 and 10. In these grade levels, however, students were assigned to classes on the basis of their science ability. Each of the three ability levels received a different general science curriculum although many of the topics were the same in order to facilitate transfer from one ability level to another.

About 40% of students in Western Australia leave school at the end of grade 10. Those who remain prepare for the Tertiary Admissions Examinations which are given at the end of grade 12. Performance on these subject specific examinations determines access to free tertiary education with only about 50% of those to write the examinations attaining university admission.

Science study was elective in grades 11 and 12 and those choosing to study additional science selected one or two subjects from physics, physical science, chemistry, biology, and human biology.

METHOD

Although there was no intervention planned in the study, a participant observation design was utilized to collect a range of data which included classroom observations, interviews with teachers and interviews with

students. The primary data were qualitative and were carefully interpreted by the research team. The general beliefs about learning and curriculum that were held by the researchers were that higher cognitive level outcomes were an important goal for a high school science curriculum and that students learned by constructing their own knowledge as a result of active engagement in learning tasks.

Sample

Fifteen science teachers from two co-educational high schools serving medium socio-economic level families in the metropolitan area of Perth, Australia participated in the study. Twelve of the teachers were male and three were female. Each teacher was observed teaching several lessons to three or four different classes during the study.

Design

The main component of the study was an ethnographic investigation of high school science activities. The database consisted of field notes from observation of approximately 200 science lessons, written self report data on student engagement, questionnaire data from teachers and interview data from teachers and students. Data collection occurred in three distinct phases.

Phase one. In the first phase, nine teachers (six male and three female) from Private school were observed for a period of 6 weeks. During the initial 3 weeks, five grade eight classes were observed by two trained observers for approximately 8 to 12 lessons during a physical science topic.

In a second three-week interval, additional observations were conducted in grade 9 general science classes and in grade 11 elective studies in chemistry, physics, physical science, biology, and human biology. These data enabled hypotheses formulated on the basis of the grade 8 observations to be tested in other grade levels and science topics.

Phase two. The second phase of the study continued for 12 weeks and consisted of observations of six volunteer teachers (all male) from Public school. In contrast to the procedures adopted at Private school, where

observations were focused on classes in a specific grade level, the data collecting schedule was based on a specific teacher rather than a selected grade level. Observers tracked a teacher for a period of approximately a half a day. Observations were undertaken each day of the week, and the schedule was changed every two weeks.

Phase three. The third phase of the study involved formal interviews of teachers and students. All 15 teachers and 86 students were interviewed using standard protocols. A stratified random sampling procedure was used to select students from each science class at Private school. No students from Public school were formally interviewed. The interviews were tape recorded and were transcribed at a later time.

Classroom processes. Narrative records were taken during each lesson to provide a descriptive summary and time log of the activities. The observations initially focused on cognitive interactions between teachers and learners as students participated in science activities. Student work was described in terms of science content, cognitive demands and activity structures. The students who participated in the interactions were identified and the cognitive level of each interaction was coded using a procedure described by Doyle (1983). A four category system was used to code student contributions as factual recall, comprehension, procedural or opinion.

Teachers and students were interviewed informally during the first two phases. The information obtained from these interviews was incorporated into the field notes and was interpreted along with the descriptive data obtained by direct observation.

Data Analysis

The data were interpreted by individual researchers immediately after collecting the field notes. At this time assertions were formulated and the data in the field notes were used to support or refute previously formulated assertions. The team of data collectors discussed and pooled assertions at

regular intervals throughout the study.

RESULTS AND DISCUSSION

The results are presented in two sections which deal with activity structures and academic work.

Activity Structures

In the two high schools studied, all science classes, grades 8 - 12, met for six 40-minute periods per week. Most classes scheduled one double period per week for laboratory activities. However, not all scheduled laboratory periods were used for laboratory work; frequently, regular class activities were continued during time that was scheduled for laboratory activities. In higher grades, teachers tended to adhere more closely to the plan of two-thirds of instructional time devoted to class work and one-third to laboratory work.

In the classes observed, four major types of activities were noted: whole class interactive, whole class non-interactive, individual seat work, and small group work. As would be expected, the academic work and the activity structures in which the work was embedded were mutually interactive. The work planned by the teacher required a certain set of activities, and the activities that were used constrained student engagement opportunities. Each of the activities used in this study are discussed below.

Whole class interactive activities occurred when the teacher dealt with the class as a whole and interacted with one student at a time while the others listened. These activities were the most predominant type and occurred in most classes for more than 50% of the time allocated to science. Activities in the category included teachers presenting content in a lecture mode, but with frequent questions being asked of students to increase their engagement. It also included student initiated questions, discussion as part of a demonstration, review of answers prepared by students in response to homework assignments, discussion of science related incidents in the news or from other students' experiences, review in preparation for tests, and

other familiar instances where the teacher was the center of an on-going dialog with individual students regarding the content of instruction.

Whole class non-interactive activities were used when teachers introduced a new topic, summarized a topic before going on to another one, or increased the pace of instruction. Films, videotapes, and filmstrip activities were carried out in a non-interactive mode. For most teachers, the amount of time using this mode of instruction was relatively small (less than 20% of total instructional time) if audio-visual based instruction was excluded.

Individual seatwork provided students with independent practice on academic tasks and allowed for transfer of information from the chalkboard or the teacher's head to student notebooks. Seatwork also served important functions in classroom management. One of the most frequently used behavior management techniques to redirect students back on task during whole class activities was for the teacher to require students to copy a definition, an important conclusion, or a major idea in their notebooks. Teachers would dictate the statements to the students or write them on the chalkboard and students would copy, usually without speaking. Somehow, this activity was perceived by students as having top importance, and when teachers said copy into your notebooks, students became engaged in the task quickly. Teachers often relied on this pattern of behavior to reduce noise and to ensure that nearly all students were on task. Copying tasks tended to be short, perhaps only a sentence or two, and they occurred usually one to three times per period.

Individual seatwork also took on other forms including completion of worksheets, exercises from the textbook, and outlining (or note taking) as students read silently in the text. These activities tended to be of low cognitive demand and they often occurred near the end of the class period.

Small group activities occurred most often when students worked in teams to collect data in the laboratory. Small group discussions occurred

infrequently in all classes, and were only used to a significant extent in biology classes in grades 11 and 12.

Academic Work

Results concerning academic work are presented and discussed below in terms of six assertions.

Assertion 1: The assessment system was used to motivate students and had a focusing effect on the implemented curriculum.

Rowe (1974) and Doyle (1983) argued that the reward structure operating within classes was an important force that needed attention before the effects of other instructional variables could be fully understood. The results of this study lend support to that view. At all grade levels, and in all classes, teachers constantly motivated students by referring to tests and exams. Two trends were evident. Work identified as likely to be tested had a higher status than work not so identified, and activities assumed importance only if they were associated with learning for an assessment or were directly assessed. Consequently, learning for the test, copying notes from the chalkboard or from the textbook, completing laboratory reports, and homework had a high status in most classrooms.

Note-taking was a common activity in all classes. Students usually endeavored to get the notes down because they were directly tied to the assessment system or because they needed the notes to prepare for tests. However, note-taking activities took an inordinate amount of time because the pace was usually determined by the last person to finish. Students who were off-task during note-taking activities often prolonged the allocated time with the result that early finishers were off-task as they waited for an additional assignment.

In all classes students were required to complete laboratory reports in a prescribed format and submit them for grading. Students worked together to complete the report, many copied from others, and in some cases the teacher actually wrote the results and interpretation onto the chalkboard for students to copy. Grades for the report were based on completion and

"surface features" such as neatness and adherence to the prescribed format.

The following vignette is an example of the concern that students had for obtaining grades and the relative lack of concern for accurate reporting. During a grade 11 chemistry laboratory, Kevin hypothesized that a contaminated stirring rod was the probable cause of an unexpected silver chloride precipitate. The teacher commended Kevin for his interpretation and suggested that an explanation be included in his laboratory report. "No way!" retorted Kevin, "I'd rather do it again and ignore the precipitate." Kevin's behavior was consistent with the general view of needing to have the correct answer in order to gain full credit, and a pervasive view that there is one acceptable answer which students are expected to report.

Assertion 2: Teacher expectations for student performance and achievement affected the implemented curriculum.

All teachers emphasized the importance of completing the academic work in higher ability classes. They stated that students needed to know the content of grade 10 in order to succeed in science courses in grades 11 and 12. In contrast, they noted that there was less pressure to finish the science course with lower ability grade 10 students because these students were not likely to remain at school for grade 11.

Teachers frequently commented on the difficulty of teaching science to lower ability students from grades 9 and 10. However, there were signs that teachers did not always make the effort to ensure that these students understood the science content. One teacher explained that school constraints resulted in low ability students studying a science curriculum that was often inappropriate to their needs. Consequently, he was not certain that he had taught the lower ability students much science content and he said that he concentrated more on attitudes. He believed that low ability students could not learn a lot of science facts, however, "they were good at taking down notes; and they liked note-taking activities because they were not challenged to think and knew that they wouldn't make a lot of

mistakes". The observations suggested that low ability classes received a "bare bones" type of course that did not deviate to any great extent from the material in the textbook. There were few examples of interactions that demonstrated that students enjoyed the content or perceived it to have relevance to the world in which they lived. Newsworthy topics discussed in other classes, such as sperm banks and hazards of nuclear fallout, were not discussed to the same extent in lower ability classes.

In most cases teachers completed the course for lower ability students as soon as possible and then filled the remainder of the scheduled time with "busy" work. For example, in one lower ability grade 9 class students were allocated 80 minutes to complete a crossword puzzle. An additional 80 minutes were scheduled to watch films on insects and arthropods. In both instances the teacher acknowledged that the films had not been previewed before screening. Each of the films contained content that was at a cognitive level beyond most students in the class, and discussion did not precede or follow the screening of the films. Through the use of whole class, whole class interactive, and individualized activities, the teacher completed the topic on insects in less than two-thirds of the time taken for an intermediate ability class taught by the same teacher.

In an interview, a Public school teacher noted that there was more scope for laboratory work with advanced level students because of their superior independent study skills compared to lower ability students. This viewpoint was representative of the interview data obtained from all teachers. As an example of the manner in which teachers distributed time to laboratory activities the following details are provided for one of the participating teachers from Public school. The teacher was observed in four classes: A grade 9 advanced level class working on the Introductory Chemistry and Insects topics; a grade 9 basic class working on the Astronomy and Insects topics; a grade 8 heterogeneous group working on the topic Mechanics; and a grade 11 Biology class. During every observed lesson the grade 9 advanced students were provided with opportunities to participate in laboratory

activities. The total time allocation for laboratory activities was 42%. In the case of a heterogeneous grade 8 class, 42% of the time also was allocated to laboratory activities. In contrast, no time was allocated to laboratory investigations in the grade 9 basic class. Similarly, no time was allocated to laboratory activities in grade 11 Biology. When he was questioned about these data, the teacher explained that basic level students could not be relied on to work during laboratory activities or to respect equipment.

Assertion 3: Teachers endeavored to cover the curriculum in the prescribed time whether or not learning occurred.

When planning the science program, all teachers partitioned the year's work into topics to be covered each term and subsequently planned the content to be covered each week and in each lesson. The constraint of having to cover nine topics per year determined that each needed to be taught in approximately 4 weeks. In most instances the work was covered in the scheduled time and students completed a test before commencing a new topic. On occasions when additional time was necessary for a topic, teachers allocated less time to the next topic.

The focus of the implemented curriculum tended to be on covering planned content rather than ensuring that students developed depth of understanding. All teachers stated that it was important for them to complete the topics in the scheduled time so that students could take tests and exams having completed the requisite content. A consequence of this concern with covering content was that teacher explanations dealt with "surface features" of the content and frequently did not probe to the depth necessary for student understanding. In many cases, complex content was presented for students to learn by rote, and there was little probing of the underlying logic. For example, a teacher truncated a potentially interesting discussion on applications of grafting to the growth of seedless oranges and bananas in order to present information on sexual reproduction. The discussion on

sexual reproduction completed a set of discussions on types of reproduction in which each was treated in a superficial manner that involved some input from the teacher and responses to questions by a small number of students.

The following example is illustrative of the manner in which science content was presented in a way that was not responsive to student learning needs. The example involves a male teacher presenting similar content to two heterogeneous grade 8 classes. The teacher wrote the following problem on the chalkboard. A submarine hatch has a surface area of 0.8 square meters. Calculate in Pascals the water pressure pressing on this hatch if the total force on the hatch is 400,000 Newtons. Most students did not have the concept that division of two numbers could result in a number that was greater than the numerator; they did not understand the formula P= F/A; and they did not know what was meant by Newtons or Pascals.

After considerable interaction the teacher finally worked the problem on the board and asked whether there were any questions. A boy asked: How'd you get it? The teacher attempted an explanation and concluded: "Anyway, it is 500,000 Newtons per meter squared and that is Pascals. Mathematically that is a little beyond you. Never mind, we'll go on with Liquids now." When a girl asked about Pascals the teacher replied that "they are a unit of pressure".

The teacher had an opportunity to modify the lesson with a second grade 8 class. However, the only change was that the teacher provided a diagram of the hatch and explained the importance of being able to solve similar problems in grades 11 and 12. The students were as confused as those in the previous class had been. Once again the teacher demonstrated how to get the correct answer but did not explain the reasoning underlying the formula or the terms Newton and Pascal. Furthermore, the arithmetic was not made easier by selecting different numbers for the problem.

In each of the above classes, the academic work was covered, but with few opportunities for students to clarify misunderstandings. The focus of the activity was to obtain the correct arithmetic answer and to label it

with the correct unit for pressure. The science involved in the example was not discussed nor was the example related to prior activities from the same topic.

Assertion 4: The need to engage simultaneously in more than one task made student learning difficult.

A frequent problem observed in conjunction with note-taking activities was that teachers expected students to engage simultaneously in more than one activity. For example, as students copied notes it was quite common for teachers to clarify or elaborate on points contained in the notes. The majority of students tended to continue copying the notes when these discussions were taking place. In one instance, a teacher synthesized information from a number of sources as he explained the content in the notes. The explanations were most informative and represented a potentially rich means of elaborating the concepts being taught. The main problem with the strategy was that students were listening to an explanation about one aspect of science content at the same time as they were copying and presumably thinking about related, but different science content. In these circumstances it was difficult to see how students could benefit from the note-taking activity or the teacher explanation.

Assertion 5: Algorithms and procedures were used to reduce the cognitive demands of the work.

Doyle (1983) defined procedural tasks as those that involve the use of standard routines to generate correct answers. Procedural tasks were differentiated from tasks which require an understanding of why a procedure works and when and how to use it. Doyle noted that the use of an algorithm does not necessarily facilitate understanding of why the algorithm works or when it should be used. In this study, the emphasis on quantitative aspects of science in all grade levels was on learning how to use procedures and computational efficiency. In all of the grade 11 and 12 subject areas, teachers provided students with type examples, algorithms, and rules of

thumb to reduce the cognitive demand of the work and to enable students to cope with the work in a procedural manner. For example, students were given up to 10 examples of the same type of problem to enable them to recognise the type if it occurred in an exam. The general approach for solving this type of problem was routinized as a result of working a relatively large number of similar problems. As a consequence, students were able to obtain the correct answer without necessarily understanding the science involved in the problem. Student interviews indicated that many students were able to solve complex problems by applying a formula in a systematic manner that had been rote learned. Discussion of the problems indicated that students had scant knowledge of scientific principles, but had learned approaches to obtain correct answers. In physics and chemistry classes the academic work in which students engaged most often involved routine applications of procedures, algebra or arithmetic. The scientific principles underlying problems were rarely addressed in class.

Assertion 6: The cognitive demands of the work were low.

The actions of the teacher and students often reduced the cognitive demands of the academic work for most students in the class. Frequent examples of this occurred when teachers asked a question at a relatively high cognitive level and then rephrased it before any students could answer. The question to which students finally responded often required a dichotomous selection such as a yes or a no, or a choice between two given alternatives.

Target students (Tobin and Gallagher, in press) were those who dominated whole class interactions in this study. Their actions in asking and answering most questions reduced the cognitive demand for their classmates. For example, in one grade 11 physics lesson the teacher worked a difficult problem on the chalkboard and called for students to contribute to the solution. Three or four boys provided a number of suggestions in this activity, mainly by calling out. In this example, the higher cognitive level work was carried out by the teacher as he worked the physics problem

step by step on the chalkboard and by the more able students as they responded to teacher questions. Most students watched and listened to the teacher and listened to target students respond to questions. The higher cognitive level work was done for them. Their role was to remember the correct answers and the procedures to follow when solving similar problems. On several occasions the teacher left the students to solve algebraic expressions, however, since the answers were provided by the teacher after a short time, those who could not do the work were not required to do so. For these students the task was to copy answers from the chalkboard into their notebooks.

There were some notable exceptions to the above trends. The cognitive demands of the academic work were high in grade 11 and 12 biology classes. This was due mainly to the emphasis in discussion on questions from the text. The majority of the time was devoted to discussion of questions that students had attempted at home. Consequently, most new content was introduced for the first time in the textbook. Teachers used the lessons to elaborate on student responses and to extend and clarify concepts from the text.

Texts were not used as well in other subjects or grade levels. The textbooks used in grades 8 to 10 focused on providing science content, and the questions at the end of each chapter required students to locate specific science content. Few questions necessitated higher cognitive level processes. The teachers often asked students to make summaries from the textbook and to answer the end-of-chapter questions. The cognitive demands of such activities were low and usually involved students in a brief search through the text for relevant information and transcription of the information into their notebooks.

Physics and chemistry textbooks tended to be used as a means of elaborating on information presented by teachers in grade 11 and 12 classes. Although the end-of-chapter questions were a potential source for higher

cognitive level work they were not often used, and when they were, the "search and find" technique described above was usually used. Students were frequently requested to solve problems from the textbook and from supplementary texts and worksheets. Only infrequently were students asked to solve qualitative problems. This emphasis in class was a direct reflection of the questions asked on the external examination papers in chemistry and physics.

The human biology course was concerned with memorisation of a large number of facts. Consequently, the implemented curriculum focused on presenting facts in a variety of ways. Lessons were characterised by the teacher providing factual information, the students completing worksheets with the assistance of a textbook, and the teacher correcting student responses to worksheet questions in a whole class mode.

In grades 8 to 10, laboratory activities tended to be of a cookbook type with a strong emphasis on following procedures in order to collect data. There was little emphasis on planning an investigation or on interpreting results. Teachers tended to provide the procedures to be followed and a table in which to record data. Recipes for most experiments were in the textbook, in a manual or on the chalkboard. The typical pattern was for data collecting activities to continue until approximately 5 minutes of the lesson remained. At this time the teacher issued instructions to stop work, pack away the equipment, and write the conclusions. For example, in an investigation of the effect of green plants on the amount of oxygen in a jar, there was no initial discussion on the need to control variables or on the purpose of burning a candle in each of three jars. The students followed a recipe as they collected data in a highly structured manner and interpretation was completed in a whole class setting.

FURTHER DISCUSSION

This investigation of academic work in science classrooms has identified a number of factors that are not optimal. However, the task of changing classroom processes is complex and unlikely to be easy. Initial data

interpretation indicated that rewards, teacher expectations, external factors and student characteristics combined to shape the science curriculum. However, intensive discussions with teachers suggest that the reward structure and teacher expectations are influenced by teacher beliefs about the nature of the curriculum that is most appropriate for students, how students learn, and the extent to which teachers can control the curriculum.

It was apparent throughout this study that students were continually motivated by assessment in the form of homework, tests and exams. Rarely was the importance of topics related to the world outside of the classroom. The focus was on completing the work in a manner that allowed students to succeed on a test, exam paper, or an assessment activity. The influence of rewards was pervasive and constituted the most common form of extrinsic motivation in all classes. Although many of the teachers in this study recognised deleterious effects of the assessment system they did not feel that they had the power to change the form or frequency of assessments. Teachers stated that responsibility for changing the curriculum and the assessment system was vested in the head of department, school administrators and state education authorities. The two heads of department involved in the study also accepted little responsibility for changing the type of assessment.

The teachers' perceptions that external factors had a strong influence on the curriculum were supported by our observations. For example, the State Department of Education provided guidelines on what ought to be taught, and teaching strategies to be used. All teachers were heavily reliant on text materials and little adaptation occurred. When deviations from the student text were observed they usually involved use of information or materials from another text. Consequently, adoption and use of appropriate texts is a means of improving the quality of student engagement. Evidence of this was observed in grade 11 and 12 biology classes where the

end-of-chapter questions did not lead to "search and find" activities, but required students to understand the science from the chapter and to construct higher cognitive level responses.

Interviews with teachers revealed that most teachers accepted responsibility for student learning. When questioned about the most effective learning activities, teachers usually replied in terms of clear and logical explanations of content. It was as if teachers believed that learning could be enhanced to the greatest extent by presenting the material in a more appropriate manner. Seldom was the form of student engagement mentioned as an important variable. Furthermore, teachers viewed the curriculum in terms of content to be covered, and student learning was demonstrated by success on achievement tests. Accordingly, it is easy to see why teachers "broke down" the content so that students could observe and learn correct answers. In addition, it is easy to understand why teachers assisted students to succeed in conceptually difficult subjects like chemistry and physics by teaching them procedures to use in order to arrive at correct answers to problems.

With so many factors having the potential to influence the implemented curriculum, we were surprised to find that the academic work was so similar in classes taught by different teachers in the same school and in the two schools involved in this study. An hypothesis that is plausible is that the results only apply to specific schools within Western Australia. The hypothesis is tenable because of several fundamental differences in the way that schools are organized and run in Western Australia compared to other parts of the world. For example, Western Australia has a centralized system of control and a statewide external examination system at the end of grade 12. In contrast, most states in the USA have local control of education and do not have statewide examinations. However, recent studies in Georgia (Tobin, Espinet, Byrd & Adams, 1986; Tobin, Espinet & Byrd, 1986) obtained results that closely parallel those obtained in Western Australia. Similarly, results reported by Gallagher (1985) for schools in Michigan

indicate that academic work in high school science classes is strongly influenced by the local assessment system.

Similarities in the results of our research in Western Australia and parts of the USA caused us to consider the possibility that other factors were even more important than those discussed above. Our recent research (e.g. Gallagher, 1985; Tobin, Espinet, & Byrd, 1986) suggests that teachers' knowledge and beliefs are potent forces associated with the implemented curriculum. Further research is needed to provide insights into the way that knowledge of science, pedagogical knowledge, and beliefs about teaching and learning influence the implemented curriculum. Since science educators inevitably will be concerned with improving the implemented curriculum, there is a need for further classroom research which focuses on improvement of teaching.

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